NASA TECHNICAL TRANSLATION NASA TT F-16,008

THE PLANET'S SOIL RESOURCES

V. A. Kovda

Translation of "Pochvennye resursy planety",
Priroda, No. 8, Academy of Sciences, USSR,
1974, pp. 2 - 12

(NASA-TT-F-16008) THE PLANET'S SOIL RESOURCES (Scientific Translation Service) 32 p HC $3.75 CSCL 08G
N75-13368
Unclas
G3/43 04971

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C. 20546 DECEMBER 1974

THE PLANET'S SOIL RESOURCES

V. A. Kovda*

The influence of man and his many-sided activities on nature began to be universal in our times, and on a constantly increasing scale. Man has begun to feel the limitations of resources, space, and the cycle of matter on this planet, and has come to understand his deep historical and biological ties with the biosphere, and his responsibility for its preservation and improvement of our natural surroundings. Scientists and technologists have realized the importance of reorganizing contemporary industry, the urban, rural, forest, hydro and mining economy and transport, for a wiser utilization of /2**

Victor Abramovich Kovda, director of the Institue of Agronomy and Soil Science of the Academy of Sciences USSR (AN SSSR). Soil scientist. Author of (caption continued on following page)

---

*Corresponding member of the Academy of Sciences USSR. In this article, the author utilizes materials of his lecture at the Xth International Congress of Soil Scientists (Moscow, August, 1974), and also yearly reports of FAO.

**Numbers in the margin indicate pagination in the original foreign text.

natural resources, optimization of the environment, preservation of the wealth and beauty of the world, and a fuller and more satisfactory fulfillment of the material and spiritual needs of man.

(Caption continued)

works on theoretical problems of soil science and amelioration, and also utilization of new land during construction of irrigation systems, and amelioration of solonetz (strongly alkaline soils) and salty lands. In 1958 - 1965, he was director of the Department of Exact and Natural Sciences of UNESCO (Paris). At the present time, he is president of the International Society of Soil Scientists, and president of the International Scientific Committee on the Problems of the Environment (SCOPE). He has published a number of popular articles in "Priroda" (No. 9, 1971; No. 1, 1972, and others)

The International Society of Soil Scientists and UNESCO jointly developed and adopted the multi-year program "Man and the Biosphere", in which particular attêntion is paid to the problems of learning and utilization of the soil cover as a component of the biosphere. The same purpose is served by the UNESCO/FAO project "Soil Map of the World", which at present is nearing the stage of completion. An evaluation of the correct role of the soil cover in nature and in the life of the community becomes possible only if we have a coordinated nomenclature and systematization of soils, particularly composite soil maps of the continents, based on the generalization of newly collected data. The evaluation of the role of the soil cover in the biosphere and in providing abundant supplies of biological raw materials and valuable products has been a central item in the program of the Tenth International Congress of Soil Scientists.

The World Soil-Ecological System

Among the many problems of the protection and utilization of the biosphere resources, as a medium surrounding man, the problems of the planet soil cover play a particularly important role. Basic functions and processes determining the normal dynamics of the biosphere take place due to the availability of cosmic solar energy and photosynthesis. Photosynthesis utilizes this energy and gives rise to organic matter, establishing a vegetable blanket*. But behind the details of this most important process remains in shadow the enormous role of the soil cover in these processes, determining the normal function of the biosphere, and the existence of life itself. This is why it is desirable to point out certain features of the soil cover, such as the components of the biosphere, features which at the first glance would appear banal, but which, in reality, are underestimated, and sometimes simply not understood sufficiently.

Photosynthesis accomplished by plants under dry conditions is unthinkable; it is impossible outside of the ecological setting and, particularly, without the soil cover. The soil cover forms on the planet Earth a specific biochemical sheath. Being the component of /3 the biosphere and the product of interaction of living matter with minerals, soils present an area in which organisms are concentrated, along with their energy, products of metabolism, and death.

The soil and plant cover of the dry land represent an inseparable entity — a world soil-ecological system in which the soil and plants function together.

One can add here that there is also another world ecological system possessing similar function to those in the biosphere — this is the World Ocean. The ocean, with the life that was born in it, played the primal role in the biological history of our planet, in the creation of the biosphere and in the formation of the great biological cycle of matter, involving 13 - 15 light elements and many isotopes. Approximately half a billion years ago, plant life appeared on the dry land, and gradually occupied it. And it was just afterwards that the soil-forming process was initiated on the planet. In the course of a very complex history, the soil cover of the planet known to us was formed, including its humus envelope, which is an energy accumulator. During the last 300 - 400 million years, enormous quantities of solar energy were bound photosynthetically,

---

*A. A. Nichiporovich. Fotosintez i biosfere (Photosynthesis and the Biosphere). "Priroda", No. 6, 1972.

storing reserves of organic matter. At the same time, the atmosphere was formulated with current proportions of nitrogen, oxygen, and carbon dioxide. To a considerable degree, this process was determined by the formation of the biomass and its degradation on the dry land, i.e., was effected by the terrestrial plant formations, which could not exist without the soil cover.

The organisms (plants, animals, microbes) and soils add up to complex ecological systems (biogeocenoses), which vary depending on history and specific features of the geographical medium. The basic functions of life on the Earth are effected by the "organisms $\rightleftarrows$ soil" system by creating vegetable organic matter, utilized by herbivorous animals, the zoobiomass of which is then used by numerous chains of parasites, predators, necrophages, soil invertebratae, and microbes*.

The soil humus, being the most important product of the soil-forming process, proves to be also one of the last chains in the food cycles.

The vegetable fallout, products of metabolism and dead residues partly form a bed, and are carried away by rain water, but the major part of their mass enters the soil. The soils are particularly important as the basic habitat of living matter (rhizomes, worms, insects, lower inverterbratae) under the extreme conditions of deserts, high-mountain plateaus and steep slopes, tundras, and arid lands. Under such conditions, rhizomes form 95-97 % of the total phytomass.

Based on the sum of plant rhizomes and reserves of humus, we can consider that the predominant part of the living matter of dry land, and of potential biogenic energy, is concentrated in the soil envelope of the earth, in its humus sheath**.

---

*V. A. Kovda. Soil Cover and the Biosphere. "Priroda", No. 1, 1972.

**V. A. Kovda, I. V. Yakushevskaya. Biomassa i gumusovaya obolochka sushi (Biomass and the Humus Sheath of the Dry Land). In the collection: Biosfera i eye resursy (Biosphere and Its Resources). Moscow, "Nauka", 1971.

It is necessary to stress the role of microorganisms in life of the soil. Our calculations, performed together with I. V. Yakushevskaya, have shown that the dynamic annual reserve of microbial mass in soils either equals or exceeds by 1.5 - 2 times the ground phytomass*. In black earth, river bottom land, and cultivated soils, the microbial biomass reaches 20 - 50 ton/ha/year.

Thus, the initial synthetic link of the great planetary cycle of chemical elements and binding of cosmic energy in biogenic matter, takes place on dry land with compulsory participation of the soil cover.

The second — destructive — half of the great biological cycle of matter is effected also with the participation of the soil cover of dry land. It could be that the role of soils in this process is even more important than in the initial link of this cycle. The biomass of root systems, equal to or exceeding the ground biomass, is inside the soil. This causes both the higher and, particularly, lower herbivorae and, consequently, carnivorae to concentrate also in the soil levels. Therefore, the major part of biomass of the living world is concentrated in the soil levels. The same should be said about the biomass of microorganisms, 99% of which are inhabitants of the humus level of soils and form in them a microworld of ecosystems, which are more complex and historically older than the plant-soil ecological systems. The living organisms inside the soil and the microworld of fungi and microbes form the humus sheath of the soil cover, and the final destruction and mineralization of organic matter.

All the above indicates that the soil cover and, particularly, the humus sheath of dry land and shallow waters play the role of a general-planetary accumulator and distributor of energy which passed through the photosynthesis of plants. They act as a universal screen

---

*Ibid.

retaining in the biosphere the most important biophilic elements (carbon, nitrogen, phosphorus, sulfur, calcium, potassium), and preventing their geochemical runoff into the World Ocean.

Each individual ecosystem (biogeocenose) constitutes a self-regulating mechanism, formed as a result of many thousand years of evolution. The components of the biocenose (plant, herbivorae, carnivorae, lower organisms and microbes, soils, near-ground atmosphere, and subsoil waters) are closely interconnected by mutual features — the same territory, general flow of energy, exchange and cycle of biophilic chemical elements, constant seasonal physical and biochemical conditions, trophic relations, and the quantity and mutual adaptability of numerous species of organisms.

The soil, being the product of biogenecenosis, at the same time is the mirror of its history and properties.

Finally, the soil cover together with its microworld plays the /4
role of universal biological absorber (adsorbent), cleaner (purifier), neutralizer of contaminations, and mineralizer of the residues of any organic matter of the dry land. It is due to this function of the soil cover in the biosphere that humanity so long (in the historical sense) relied on "self-purification of nature" from these waste and refuse materials which the growing population and economy was throwing away into the outside environment.

However, during the last 150 - 100 years, the growth of industry, agriculture, transport and mining, and of cities, began to disturb the normal functioning of the "soil-plants-animal" system.

Current State of Soil Resources

The soil resources of the planet are limited with respect to area and quality. Up to 70% of dry land is not ideal, needs improvement, and requires amelioration of some kind. The problem becomes more critical since, during the last 75 - 100 years (particularly in the process of development of pre-socialistic society), the soil cover of the planet began to decrease. At first, either no importance was attached to this fact, or the soil cover was accepted primarily as "consumer's need", as a substrate for production in agriculture and forestry. But fears caused by possible changes in the world balance of oxygen and carbon dioxide, by a decrease of reserves of biologically pure water, and eutrophication of water reservoirs, caused attention to be given to the role of the soil cover as the most important biosphere component. This new consideration of the planetary role of the soil cover on the Earth, originating with V. V. Dokuchayev and V. I. Vernadskiy, became more complex in the following years. The soil cover of the dry land, whose planetary role is characterized above very briefly, is decomposed, lost, and degraded at an increasing rate.

There are data which, in my opinion, are not exaggerated, that in historical times altogether about 2 billion hectares of earth were lost*. I shall remind you that at the present time, about 1.5 billion hectares of earth — that is, about 10 - 11% of the dry land — are under agricultural cultivation on the whole planet. Each year, about 6 - 7 million hectares of soil are lost in the world.

According to FAO data, man utilizes as plowlands, pastures, and meadows only about 23 - 30% of the dry land. If productive forests of various types are included, the number increases to approximately 50 - 55% of the dry land. All these are better agricultural areas of the planet. The remaining part of the dry land is little utilized by man, in the sense of biological production. The losses of the Earth's resources by humanity is a painful and highly undesirable process. Most of the population of the planet is concentrated in regions of ancient culture and highly productive soils. Civilization began in delta, river-bed, meadow, and black earth areas, on grass prairies and steppes. And soils of these territories began to show losses first, since it is there that there are concentrations of population, cities, industry, and intensive agriculture.

*D. N. Meadows, D. L. Meadows. The Limits to Growth. New York, 1972.

The problem of preservation of the soil cover is very serious from many aspects: from the viewpoint of world production of goods and biological raw material; from the viewpoint of the space limitation, both in the literary and figurative sense; and from the viewpoint of the normal functioning of the biosphere.

Moreover, properly organized forestry, properly organized productive agriculture, successfully performed melioration of the soil, productive hydro-economy on a scientific basis and, particularly, irrigation, can fully eliminate many negative phenomena. They can make it possible to cultivate millions of hectares of so far nonproductive land, to create highly productive dry lands in place of previous hot or cold deserts, and to balance the previously disturbed cycle of matter and normal functioning of the biosphere. It does not mean that in industry, agriculture, and urban management shortages, errors and disorders, which are generally well known, should continue. Of course not, and we should fight against them. But, at the same time, we should understand that the "industry of biological production" in the broad meaning of this word, including here agriculture, melioration, hydro- and forest economy, produces oxygen together with the biomass, and by its nature it has a beneficial effect upon the soil cover and biosphere. If we learn how to master this mechanism scientifically and technologically, we can control these processes in the present biosphere, the processes which got away from the dominance of man, and which became partly uncontrollable.

Calculations of the bioproductivity of the Earth, performed by American scientists* in connection with preparation for the Stockholm OON Conference on the Biosphere in 1972, once again confirm that — both with respect to reserves of the biomass carbon and the yearly carbon bonding — dry land is about twice as productive as the ocean.

---

*C. T. Wilson. Man's Impact on the Gloval Environment. MIT Press, 1970.

By improving the soil — the ecological medium of vegetation — by means of melioration, by working on it and fertilizing it, man can increase the biological productivity of dry lands. In addition, he can ensure normalization and improvement of the general state of the biosphere.

In the pre-socialistic epoch, the manufacture and utilization of biological production (fuels, building materials, supplies, raw materials, etc.) was elementary, without a scientific base, and often with a get-rich-quick attitude. Only on the basis of the work of V. V. Dokuchayev, which was further developed by the work of B. I. Vernadskiy, V. N. Sukachev, P. Dyuvin'o, and other scientists*, knowing already in general outline that the external environment, organisms and soil form a close combination, did man begin to apply intentionally a complex of measures and actions on various components of the ecosystem in order to obtain the maximum bioproduction. /5

Contamination and Geochemical Anomalies

The problem of contamination of soils, and at the same time of the ground, river, and lake waters, with rare (trace) elements is becoming particularly acute. It is known that the content of microelements in soils is measured in very small quantities. In those places where there are no deposits of trace elements, their normal background content is quite even and uniform in considerable areas. Geochemical anomalies of an increased content of microelements are observed only in soils and grounds directly covering the deposits, or in waters circulating through them. These rules formed the basis for the soil-geochemical methods of prospecting for deposits of these or other rare microelements**.

---

*See A. A. Rode. Dokuchayevskoye pochvovedenie v Akademii nauk v 20-30e gody (Dokuchayev Soil Science in the Academy of Sciences in the Twenties - Thirties). "Priroda", No. 5, 1974; G. F. Morozov. Genial'noye dopolnieniye k ucheniyu Darvina (Brilliant Supplementation of the Teachings of Darwin); ibid.

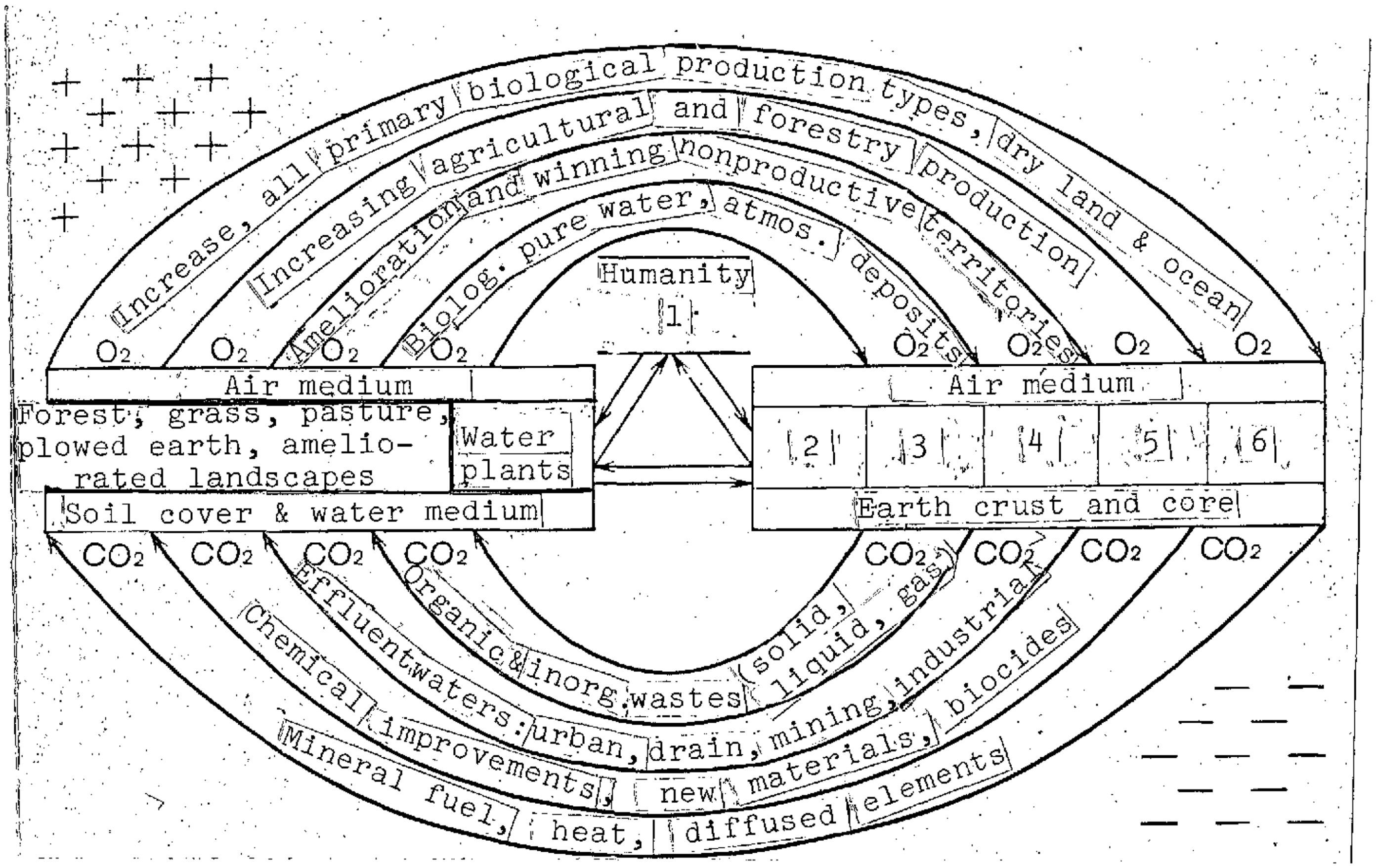
**V. A. Kovda. Osnovy ucheniya o pochvakh, t. I-II (Principles of Learning About Soils, Vol. I - II). Moscow, "Nauka", 1973.

At present, the treatment of deposits, enrichment of ores (particularly flotation), their transport and metallurgical production, slags, ash, dust, gases, industrial effluents, and immoderate use of preparates, leads to a broad disturbance of the background content of such microelements in the soil and waters as Cr, Hg, Cd, Pb, No, Sr, Be, Ni, Zn, U, Cu. The "geochemical anomalies" appear, caused by accumulation in high concentrations of elements earlier unknown in given soils. The accumulation is observed most of all in the upper 3 - 5 cm of the soil. Apparent new geochemical belts, of contents of trace elements increased by 10 - 100 - 1000 times, are formed around mining shafts and industrial complexes, along the main transport routes, and in the regions of dumping grounds and outflow of industrial effluent waters. These elements also accumulate in river beds and in bottom layers of rivers and lakes.

Being incorporated into plants, and, consequently, into organisms of animals, toxic compounds of cadmium, mercury, lead, and others, cause illnesses, poisoning, death. The elements foreign to the biosphere are transported with aerosols and reach other continents, polar regions, and the ocean.

Extensive scientific work is required to evaluate the role of transferring alien elements into the biosphere and their effects. It is necessary to compile soil-geochemical cartograms of the normal and anomalous concentration of these elements in soils, to clarify the level of their concentration in soils, and also to learn the rules governing their distribution.

Anthropogeochemical anomalies form around large modern cities (megalopolises); they appear also locally in the neighborhood of separate industrial enterprises and large animal farms. In the latter case, in addition to microelements, the soil-geochemical anomalies will contain also macroelements: C, P. N. S. K. Al, Mg, Fe. /6



Scheme of the controlled exchange of matter in the matter ⇄ biosphere system of the planet Earth

1 — science, labor, prognoses, management, capital investment; 2 — domestic economy; 3 — technologies, mines; 4 — population, cities; 5 — transport, communications, 6 — industries

According to the data of FAO and other sources, the significance of various forms of soil degradation in the world is characterized by three categories, in order of importance (see the Table).

The main losses of agricultural land are caused by building (developing) of the ground — settlements and cities, plants and factories, mines, technological enterprises, and roads, as well as erosion and salting.

In the U.S.A., up to 800,000 hectares are lost yearly by erosion and building. About 73 million hectares are occupied by inhabited points, roads, and installations. Up to 60% of the agricultural land in the U.S.A. needs amelioration, protection, and restoration of

TABLE. FORMS AND SOURCES OF THE DEGRADATION OF SOILS

I	II	III
Construction, transport, communication	Urban refuse, sewer waters	Excess of fertilizers
Erosion and silting	Industrial inorganic refuse	Biocides
Salting and solonetz (brackish, saline soil)	Mining wastes	Detergents
Organic waste	Radioactivity	
Infectious diseases and insects	Heavy metals	

productivity. France lost up to 5 million hectares of ground due only to construction of cities and facilities. Madagascar lost 5/10 of its surface due to severe erosion. To such losses, we have to add also changes produced in soils by wastes of cities, industry, and agriculture.

According to Western experts, up to 650 - 700 million hectares will still be lost for cultivation by 2000. And through the century, if the current rates of loss of land are maintained, the area of land suitable for cultivation will decrease to 1 billion hectares. Will humanity allow such a pilfering of earth resources to happen? The socialistic community, as an alternative to capitalism, should be solving and will solve the problem of preservation of the resources of the world, as a condition for the prosperity of humanity.

Is Regeneration of the Soil Possible?

Conditions under which the present soils were formed partly disappeared irretrievably and partly changed strongly, but the importance of soils for man and society continuously increases.

The soil cover serves as the basis for supplying and locating settlements and inhabited points, industrial enterprises and mines, roads and aerodromes, and resorts. The soil cover and the World Ocean are planetary acceptors of the variety of wastes from economic production activities. Many organic and organo-mineral compounds undergo decomposition in the soil and the ocean; consequently, the soil and the ocean play the role of purifiers of the planet from contamination.

In contrast to resources of fresh water, vegetation, or animal world, the soil resources are not self-renewing after destruction. Even if a new soil is formed in place of the destroyed cover, this soil is of another type.

Artificial recreation of lost soils is practially impossible, since we cannot reproduce the conditions and history of their formation. Formation of new soils in place of destroyed ones (re-cultivation) is possible, but it it very complex, expensive, and all too often ineffective. However, in spite of all these complications, the problems of regeneration of fertile soils remain on the agenda with a high priority. We can talk about evolution of a separate scientific discipline — "study of recultivation of land". The recultivation of cultivated land, destroyed by industry, represents a complex of mining-technical, engineering, meliorative, and biological measures, with the aim to provide and quickly formulate on lands, lost by technological actions, optimal cultivated landscapes with productive soil-vegetation cover.*

At the same time, in contrast to other non-renewable resources (oil, gas, coal, metals, ores), proper utilization of soils in agriculture and forestry not only preserves them, but also improves

---

*B. P. Kolesnikow, L. V. Motorina. Rekultivatskiya zemel narushennykh promyshlennostyu (problemy optimizatsii tekhnogennykh landshaftov) (Recultivation of Lands Disrupted by Industry — Problems of Optimization of Technological Landscapes). Moscow, VDNKh, 1974; Rekultivatsiya zemel v SSSR (Recultivation of Lands in the SSSR). Moscow, "Nauka", 1973.

them, and increases productivity, expressed in increasing crops of biomass necessary for man.

In the rational utilization of soils, they become more "cultivation responsive", and acquire new features unknown in natural soils. The soils respond to such measures as regulation or radical changing of their physical, chemical and biological conditions, by means of agrotechnics, chemical treatment, and amelioration.

The increasing power, universality, and size of technical means for society to influence soils represent in contemporary times the general progress of humanity and increase the standard of life. At the same time, the actions of man on soils often do not harmonize with the rules of life, dynamics and productivity of soils (either by ignorance or by the rush for cheap production). In such cases, soil processes deviate from the norm, the soils deteriorate, degrade, acquire negative properties, are disrupted or altogether destroyed (erosion, dust storms, salting, silting and petrifying).

In view of the fact that soil resources are not unlimited, but are restricted by the area of dry lands, effective utilization of /7 agricultural lands (under the condition of preserving it as a component of the biosphere surrounding the man) becomes the most important problem of contemporary times.

How Much Land is Needed by Mankind?

V. V. Dokuchayev, K. D. Glinka and L. I. Prasolov were the authors of the first soil maps of the world which led, as early as the forties, to an analysis and estimate of utilization of land resources of the planet.

Comparison of the main types of soils in the world and their agricultural suitability has shown that the general agricultural suitability of dry land amounted at that time to about 10%*.

*L. I. Prasolov, N. N. Rozov. Tipy pochv i mirovoye zemledeliye (Types of Soils and World Agriculture). Moscow, 1949.

Farming of the land was concentrated in 40% in four types of soils: black earth, dark soils of prairies, grey forest soils, and brown forest soils. On the average, 26 - 35% of these types of soils were plowed up. By now this has increased, probably, by 5 - 10%.

Out of the remaining types of soils, 6 - 13% of the red earth, alluvial, chestnut brown, and brown soils were plowed up, while grey earth (serozem), soils of savannas, mountain, desert, and podzolized gley soils — by 2- 4%, and considerably less.

However, it can be apparently asserted that the best soils have already been utilized, in general. The non-utilized lands are located in the cold or dry climate areas, in mountains and in deserts. About 30% of dry land needs artificial irrigation and a complex melioration of soils to remedy salting, neutralize high alkalinity, and improve the structure. An enlargement of agriculturally suitable lands will have to be carried out under natural conditions, which are considerably less favorable than those in earlier regions.

The picture of general limitation of earth resources of the world is confirmed by many investigators. According to the general estimate of FAO*, the resources of the world are not very favorable from the viewpoint of agriculture, and up to 70% are relatively unfertile lands.

This estimate coincides with the view of Soviet experts who consider that, after corrections for water and ice areas, up to 73.4% of dry land has low productivity, not being provided sufficiently with heat or moisture. The areas of the Earth which do not have sufficient moisture occupy 47 - 48% of the dry land. Moreover, the quality of the soils themselves in arid regions is low (salting and draining).

---

*U. N. Conference on the Human Environment, Land Degradation. Rome, FAO, 1971.

The data of FAO, which require confirmation and checking, show that the total area of land in the world potentially suitable for agriculture amounts to about 3.2 billion hectares (32 million km^2).

At the present time, about 1.5 billion hectares (15 million km^2), i.e., about half of that total, are plowed up and utilized. These are the best lands of the planet. The plowability of dry land thus reaches 10 - 11%, and general agricultural utilization, including pastures and land used for hay, amounts to about 30% of dry land.

The plowability varies considerably (from 1 - 4% to 30 - 70%) in various countries and continents. According to views of the FAO experts, the total plowability could be gradually doubled, reaching 20 - 25% of the surface of dry land. This complex task encounters, however, considerable difficulties. It requires enormous capital investment in melioration and agricultural work to obtain, improve and cultivate new lands. Already the costs of amelioration to acquire new lands has increased in Western countries 20 - 25 times, in comparison with expenses to obtain 1 hectare of land in the last century.

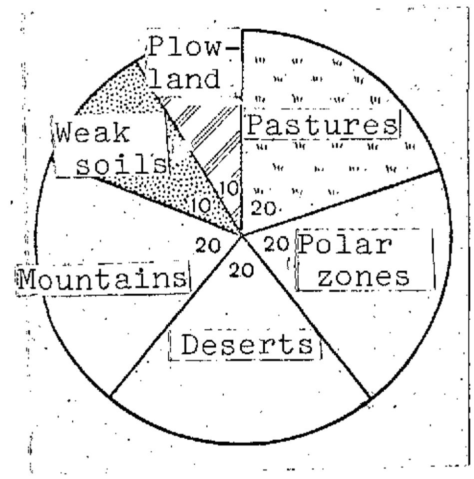
The necessity of gaining new soils for agriculture is dictated by a number of factors. They include: the urgent need to liquidate in a number of countries the existing spectra of hunger and undernourishment; growth of the size of population of the Earth (doubling in 30 - 35 years); increased need for various materials of biological origin; continuously growing losses of the area of arable land from erosion, salting, and industrial and urban construction; and relatively low world-average level of yields of cultivated fields in the majority of countries of Asia, Africa, and South America, calculated per one person of population.

Melioration — A Complex Notion

The twentieth century is the century of melioration of soils and landscapes. The technical policies of administrations, governmental, cooperative or industrial economies regarding the utilization of land riches depends to a large degree on the accuracy and timeliness of scientific prognoses and recommendations of scientists: soil scientists, genetics experts, meliorators, agronoms, geochemists, foresters, and others.

Much is determined, however, by forms of land features: some of them retard technical progress in the soil science, and some of them, on the contrary, facilitate it.

It appears to me, as a Soviet scientist, that the end of this century and the next century will open an entirely new important period in the history of soil science, agriculture, and land utilization — a period of social transformations, industrialization and complex melioration*. In the same way as the use of lime for acidic soils



Distribution of land resources on our planet. The poorly productive lands (not hatched) occupy 60% of the whole dry surface. In this number, 20% of land has a climate which is too cold (polar zones, etc.), 20% — too dry a climate (deserts, etc.), and 20% lie on slopes which are too steep. Weak soils (dot hatching) take 10%; pastures, grasses, and hay-producing land occupy 20% of the dry surface; and only 10% of land (diagonal hatching) is arable and under agricultural cultivation /8

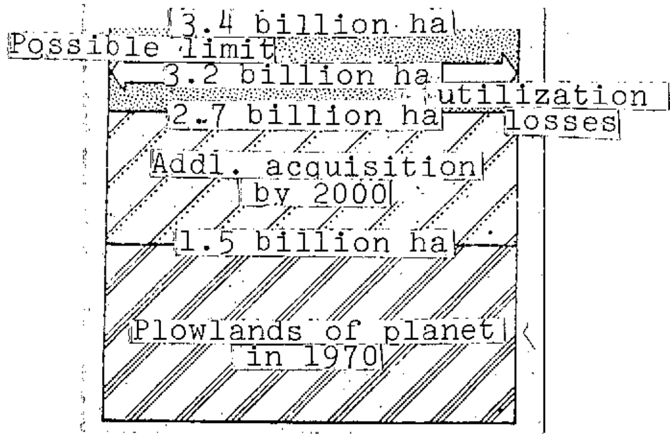
---

*An example of the complex melioration of the regions carried out on the basis of and concurrently with extensive social transformations is provided by the recently adopted long-term program of the accelerated development of agricultural production and melioration of lands of the non-black soil zone of the Russian Federal Socialist Republic (RSFSR). See: Resolution of the Central Committee of the Communist Party (TsK KPSS) and the Council of Ministers of USSR. "Pravda", No. 93 (20332), 1974.

and of mineral fertilizers opened unheard of possibilities for the increase of yields in the past, in the same way as genetics provided and will provide highly productive new types of agricultural plants, the theory and practice of radical improvements of soils and elimination from them of limiting factors, and control of the dynamics of soils, will open real possibilities of doubling or trebling the total world production of supplies and biological raw materials, and at the same time ensure conditions for preservation and improvement of the human environment.

Our planet cannot be considered as an ideal paradise. The arid and frozen deserts, stony territories, lifeless solonetz plateaus, and steep mountain slopes occupy enormous areas. They have to be improved and converted into productive cultivated cenoses. Transformation of nature and its improvement is the sphere of melioration not only of soil, but of the whole landscape, entire natural complexes.

The principle of scientifically based complex action upon the natural landscape is the basis of success of melioration. The soil constitutes a product of the long history of the locality and its environment. It is



Soil resources of the planet and prospects for their utilization. At the present time (1970), the plowland on the Earth occupies 1.5 billion hectares (dark hatching). By the end of the 20th century, about 1.2 billion hectares will be additionally acquired, and the plowland will take 2.7 billion hectares. Considering possible losses of land (erosion, salting, etc.), mankind at the present rates and technology of agricultural development would require 3.4 billion hectares of lands for its needs in 2000. However, the potential agricultural land amounts to only 3.2 billion hectares, according to FAO data. This points to the goal of at least doubling the yields. This will provide mankind with the necessary agricultural products in the present areas of utilization (1.4 - 1.5 billion hectares) the component of the current geographical situation. As a combination of specific properties, and as a component of a self-regulating ecological system, the soil possesses a certain stability — inertia — and is distinguished, therefore, by expressed "resistivity" to the applied melioration measures. Experiments have shown that the process of desalting solonetz soils proceeds considerably slower, as a rule, than was predicted by scientists and engineers. The effectiveness of horizontal and vertical drainage in lowering the level and removal of ground waters is lower than one may expect from calculations, models, or analogies. A particularly high "resistivity" of the soil cover to meliorations is exhibited when, instead of a combination of complex works for radical improvement and transformation of a territory, only one measure is applied — for instance, only provision of water for irrigation or removal of water in drying.

For these reasons, the study of needs by territories in melioration, the selection, planning, and construction of meliorative systems, and also their economic utilization, should arise from the necessity of simultaneous or consecutive meliorative and agronomic measures, not only on an arable level. It is necessary to act on all the components of the soil complex, on the whole soil-ground area, on relief and microrelief of a locality, on the ground and sometimes deep underground waters, on geochemical and water balance, on the surface and soil climate, and particularly on biology of the soil. The composition, ratios, and amounts of the meliorative and agronomic measures should not be standard. Each large territory is specific and irreproducible. Such should also be the engineering-agronomical solution of each meliorative project. It is necessary to broaden and supplement the very content of the notion — melioration*. Melioration is not only the artificial irrigation of soils or their drying. Melioration is a complex and differentiated set of

---

*V. D. Kovda, V. V. Egorov. Staryye i novyye problemy pochvennykh melioratsiy v zone orosheniya. Doklad na IV Vsesoyuznom s'yezde pochvovedov (The Old and New Problems of Soil Melioration in Irrigation Zone. Lecture at the IVth All-Union Meeting of Soil Scientists). Moscow - Alma-Ata, 1970.

capital, periodically repeated measures, changing nature and the soils, and ensuring the optimal water-air, thermal, chemical and biological systems in order to obtain high and constant crops (yields). Radical meliorations (terracing, irrigation) improve the soils for tens and hundreds of years.

Xerotization of Dry Land and Fight for Moisture

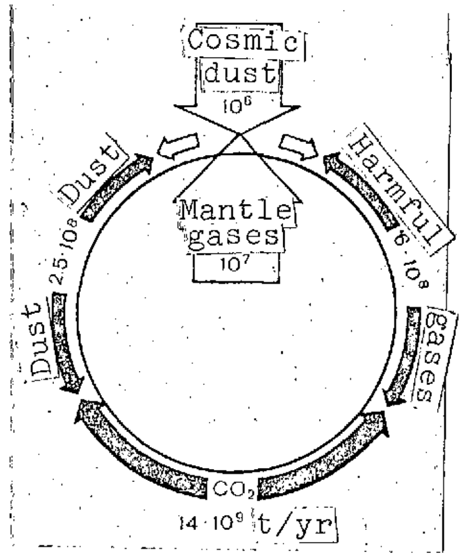
The forecasting of climatic changes taxes the wits of scientists and practicians. Are we finding outselves now in one of the climatic cycle periods when one observes a general tendency of warming up and xerotization (drying up) — or, on the contrary, do we see cooling down and a period of sharp changes of rainfall through the years? The contrast of opinions on this matter is striking. /9

The author considers, on the basis of his observations in the plains and mountains of Eurasia, Africa and South America, that there is a pronounced tendency to xerotization of plains. The tendency to increased dryness of soils is observed both on the plains of Eastern Europe and Asia. The number of actual reasons for xerotization (not speaking of lakes and their level, the regime of atmospheric rainfall) should include: 1) progressive deepening of the level of the soil ground waters, noted already by Dokuchayev and Izmail'skiy; 2) a slow but quite distinct general rise of the level of the plains; 3) incision of ravine and river hydrographic networks, and increase of their draining role; and 4) rise of the snow line in the mountains, and reduction of the river and ground waters of the plains.

The process of xerotization was increased by utilization of underground waters for consumption, farming, and transport-industrial needs. The same result is reached by the reduction of the ground waters as a result of deforestration of territories and general increase of evaporation and surface runoff. The loss of sod on pastures causes a complex effect. A lowering of the level of subsoil waters even by 50 - 75 cm increases considerably the negative effect of meteorological dryness. I shall remind you that the areas of consistently high harvests are, as a rule, on lowlands or on broad river terraces with black earth meadow soils and fresh waters close under the soil. Such are the plains of Kuban and Terek, grain areas of the U.S.A. and Canada, and Northeast China.

The increase of dryness of the plains and deterioration of the water system of soils are also enhanced by unfavorable changes in biochemistry, physical chemistry, and physics of the soils of old plowlands. In natural and recently cultivated soils, the humus layer plays an important role as a source of energy for the normal cycle of intra-soil biological and biochemical processes. By aiding the crosslinking, humus ensures optimization of the water-air properties of the soil (permeability, moisture retention, reduction of evaporation, etc.). Monocultivation, exclusion of grasses from sowing cycles, nonutilization of manure and other organic fertiliziers, overloading of pastures, etc., have caused a broadly-distributed phenomenon of depletion (dehumification). The content of humus in long-cultivated soils of Europe and America has decreased by 25 - 50% of the initial value, at the cost of the most valuable fractions. The width of humus layers was reduced, and a dense plowed soil was formed (which was facilitated by heavy tractors), the water permeability was reduced, and the packing coefficient was increased (inaccessibility to moisture), and the useless evaporation of moisture from the soil was enhanced. And, finally, the powdering of soils made them more vulnerable to water erosion and dust storms, which accelerated even more the losses of humus.

In the system of measures to fight drought, a quite important place should be occupied by all the modern measures aimed at improvement of the humus content of soils, improvement of their physical properties, and preservation of their moisture. The problem of drought is made even more critical by the necessity to double and treble the crops with the same amount of atmospheric precipitation. The newly-developed strains of cultivated plants, producing exceedingly high yields, require not less but more moisture, and more by a factor of two - three (generally in proportion to the increase of biomass). In order to obtain consistent yields of grain on the order of 50 - 60 centners/hectare, or even 80 - 90 centners/hectare, we require not 300 - 400 mm of rainfall, but 500 - 550 and 700 mm/year (depending on their distribution). It is clear, therefore, that there is a necessity to utilize all the means of melioration, chemization and agrotechnics, ensuring improvement of the water system of the soil under rainless conditions.



Current inflow of contaminating materials (in tons/year) into the biosphere. Industrial effluents (dust and harmful gases) are denoted by black arrows, and natural wastes (cosmic dust, gases from the upper mantle, and also not shown here, gases of other origin with a volume of $6 \cdot 10^7$ tons/year) are denoted by white arrows. It is seen that industrial wastes exceed the natural contaminants by at least 2 - 3 orders of magnitude (according to K. Wilson et al., 1971)

Irrigation and the Secondary Salting of Soils

Artificial irrigation of large territories exerts an enormous effect on the natural landscape, influencing tens and hundreds of meters of the ground layer, and tens of meters of the surface-bordering air layer, and affecting the water and salt system of a considerable part of the river system basin and the estuary part of the river. Unfortunately, with a few exceptions, contemporary irrigation systems are constructed and are functioning on approximately the same level as in ancient Egypt, Khorezm, or Babylon. The irrigational network of canals operates without hydro-insulation, the losses of transported water in large unprotected canals reaches 40 - 45% of water intake. The irrigation systems often take and distribute on fields and barren territories enormous quantities of excess water. The efficiency of the majority of irrigation systems does not exceed 30 -

50%, i.e., more than half of water entering the main equipment into the irrigation system is lost — in filtration, in canals, on fields, and on inundated areas. The most important condition for prevention of secondary salting, or secondary swamping with exclusion of large /10 land areas from farm use, is most of all improvement of irrigation systems themselves, and a high level of water utilization. Experience with the Soviet and American irrigation systems, and scientific analyses indicate that by introducing baffles, hydro-insulation, pipe conductors, and sprinklers, and by planning and accurately distributing water as required by plants and properties of the soil cover, efficiency can be raised to 80 - 85%.

And yet the danger of salting of irrigated soils and swamping of irrigating systems is not removed even with improvement of their technology and equipment. The reason is that the irrigation changes in a radical way the natural water- and salt-balance of the territory. In the majority of cases, a rise of the level of ground waters occurs with new irrigation systems (sometimes at the rate of 3 - 4 m per year), with the development of swamping and salting of irrigated lands.

The largest, by size and intensity, secondary salting of soils took place in the 1920 - 1940's on irrigation systems of Middle Asia (Golodnostep, Shauldersk, and Vakhsha irrigation systems, in Amudar' and in Khorezm and Tashauz oases). All this forced Soviet scientists to concentrate on development of measures which would prevent this serious phenomenon. Long expeditionary and stationary investigations, organized in the 1930's by the USSR Academy of Sciences in close cooperation with scientific institutions of the republics of Middle Asia and Trans-Caucasia, and also with planning and industrial organizations, clarified the general contemporary geochemistry of the processes of salt-accumulation on USSR territory. In the final analysis, it became possible to compose approximate and then more accurate cartograms of the regions of contemporary salt-accumulation on the whole territory of the country.

The main reasons for the continuing salting, swamping, and degradation of irrigated soils are: a) ignoring specific features of the natural soil state; b) a tendency not to provide drainage equipment with the hope of making the construction of irrigation systems cheaper; c) excessive water intake, and large losses everywhere of water on fields and in irrigation canals (which are usually not lined or covered), thus causing an increased level of the ground waters.

In the majority of countries, no analysis of the areas of salted soils is done. From circumstantial evidence, one can consider that at present there are in the world no less than 20 - 25 million hectares of salted infertile (and previously fruitful) lands. Studies of experimental meliorative stations in the U.S.S.R. and tests with large Soviet irrigation systems have shown that liquidation of the processes of salting by means of deep horizontal drainage and flushing washes is entirely feasible and quite effective.

In the Vakhsha valley, which in the 1930 - 1940's had large losses due to strong secondary salting, the salted land has been almost regained, and the yields of the long-fiber cotton plants reached 20 - 35 centners/hectare. The same may be said about the massives of salted solonetz lands in the central port of the Fergansk valley — the major base of Soviet cotton production. Considerable successes were achieved after the construction of a network of deep drainage collectors on parts of the territories of Khorezm, Tashauz, at Chardzhou oasis on Amudar', and also in Kura-Araksin lowlands, at Golodna steppes, in the delta of Syr-dar'ya, on Manycha, and in Prisivashye (obtaining good yields of cotton and rice). However, not all negative consequences of the prolonged application of irrigation systems without drainage have been overcome.

Experiments and observations have shown that, under conditions of steppe irrigation of the Russian Federal Republic (RSFSR), Ukraine, and Hungary, the new formation of ground waters and the approach of their level to the surface proceeds approximately twice or three times faster than on irrigation systems built in semi-deserts and deserts of Asia and Africa. In some 8 - 10 years, the ground waters in the steppes have risen from 15 - 20 m to the critical level (1.5 - 2.5 m), causing an unexpected salting of the black earth soils.

The first preventive measure, eliminating filtration in irrigation canals as the main reason for catastrophic disturbance of the water balance and the rise of ground waters, is construction of irrigation canals in covered pipes. The second preventive measure in new irrigation systems is the construction of vertical machine drainage in deep ground waters to remove the danger of their rising in places pointed out by predictions. On this technical basis, California and Arizona could prevent the rise of ground waters. The third radical measure of preventing and fighting salting of soils is deep horizontal drainage and its faultless functioning. And, finally, most important is providing for steppe irrigation by a new type of irrigation system, fully and automatically controlled.

Soils of the arid areas of Europe, Asia, America, and Africa have a natural tendency to become saline, or may have inherited from the past features of residual takyr and solonetz forms (nonstructuring, alkalinity). There are hundreds of millions of hectares of takyr and solonetz soils on the Earth. At the present time, their role in the biosphere (oxygen-carbon balance) is insignificant.

The Soviet, American, Hungarian, and Rumanian soil scientists developed differentiated methods of chemical, physical, planting ("self-melioration"), biological and agrotechnical melioration of saline soils. However, the practical realization of the melioration of saline soils proceeds at a slow tempo. The cost of these meliorations is not high (300 - 500 rubles/hectare), the investment is returned in 3 - 4 years, and increased productivity of fields and pastures is large.

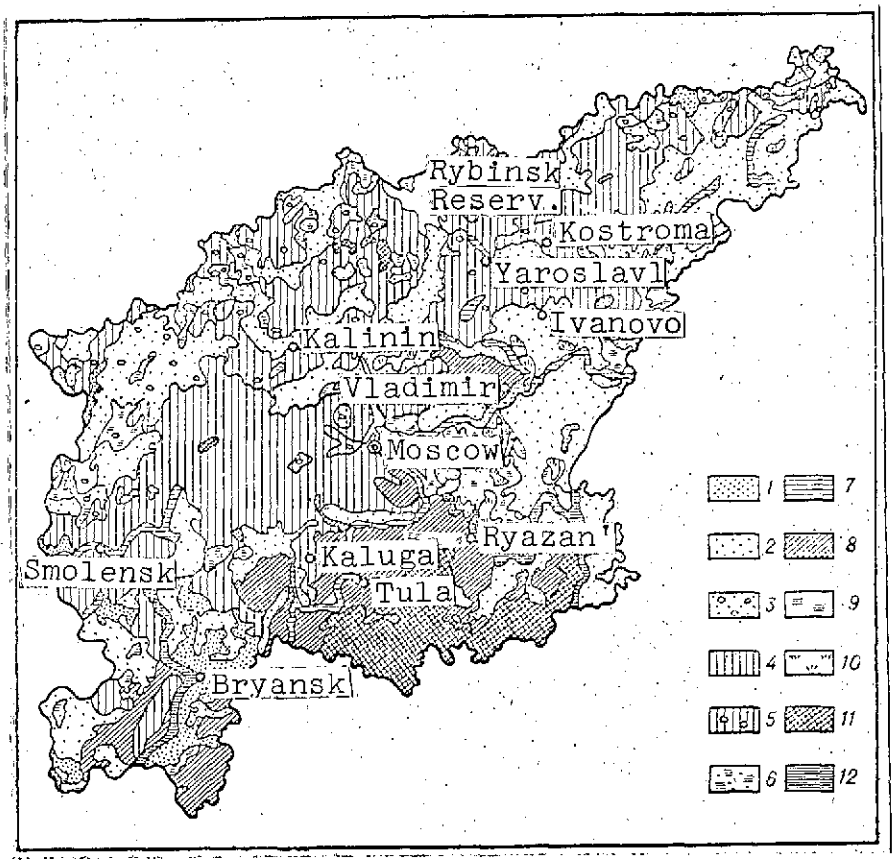
The melioration of saline soils can utilize successfully various wastes of industry, mining and farming. The melioration of /11
saline soils can improve noticeably the system of oxygen and carbon

dioxide in the atmosphere. And, most important, melioration of takyr and saline soils increases considerably their productivity.

The creation of large irrigation zones in barren subtropical and tropical deserts can be considered with interest from still another viewpoint. Namely, irrigation could stop fully the increased concentration of CO_2 in the atmosphere. According to our calculations, with an additional gain of 500 million hectares of irrigated land and a grain yield of the order of 50 centners/hectare, the phytomass grown on these areas will absorb 20 billion tons of CO_2 from the atmosphere, and will liberate into it about 15 billion tons of O_2.

Return of Wastes into Biogeochemical Cycle

In prehistoric times, the soil cover on the dry land with animals inhabiting it and microorganisms played the role of an accumulator and destroyer of various organic materials, eolians, and residues deposited in water, which were found on the surface. This function of the soil cover has been retained even now. However, the elementary overburdening of soils with wastes, rejects and similar products in some regions (cities, plants, ports), and irreversible alienation of biological production in other regions, disturb the normal exhange of matter and stream of energy in nature, as was noted already by Engels. In this connection, knowing the functions of soil-ecological systems, it is possible and necessary to organize on a scientific basis the return into the soil of at least a part of the matter and energy. It is also necessary to utilize contemporary technology, agronomy and properties of soils to destroy and assimilate foreign matter, accumulating in cities, settlements, mines, plants and factories, and on farms. How large is the quantity of this matter? The U.S.A. only, with a population of about 210 million, in 1970 produced about 1.3 billion tons of organic wastes of various types: 1 billion tons of mining wastes, and 350 million tons of various rubbish and impurities. On the



Soils of the non-black-earth (Necherzozem) center of the Russian Federal Republic (RSFSR) provide an example demonstrating the necessity and, at the same time, the intricacy of the complex melioration of land. The soils of the Necherzozem center differ in their mechanical properties. Twelve groups of soils are distinguished, and each of them requires an individual approach. According to calculations of D. N. Pryanishnikov (1945), development of a complex of melioration works would result in the Necherzozem producing additionally 1 billion poods* of grain per year (Ref. A. A. Molchanov, 1973)

*Translator's note: 1 pood = 36 pounds.

whole planet Earth, with a population of 3.5 billion, there are produced about 10 times more of such wastes, rejects, and impurities. Obviously, we are talking about a total of organo-mineral and mineral wastes on the order of 20 - 25 billion tons per year.

Metallic wastes should be fully recirculated (reused in products) in industry. Apparently, a considerable part of cellulose,

rubber, and plastics can also be repeatedly utilized in industry. But the farming organics, manure, excrements, slags, ashes, dust, industrial chemical wastes, chips and filings, wood bark, the "empty" ore in mines, and many others, should be inspected, analyzed, mixed in required proportions, composted, and spread on fields in correspondence to climatic and geochemical conditions, water balance, and soil properties, special features of cultivation, and the character of composts. The composts can be enriched with chemical additives, fertilizers, and the required microflora. In each country, region, /12
and farm, there should be organized a special service for utilization of wastes and composts (compost factories). The composts can have different aims: fertilizing for the fields, pastures, and the forests; acidic and alkaline neutralizers; physical disintegrators and aerators; adsorbents, etc. In this connection, let us cite here the experiment of Berline, where fertilizing materials and methane are produced from the urban waste, and experiments of N. Dhar in India* on utilization of the wastes of straw and metallurgical slags to produce fertilizers. Interesting also is the experiment in Armenia, where the wastes of contaminated sulfuric acid are utilized successfully for melioration of alkaline solonetz lands during irrigation, and also the utilization of lignin-sulfonate wastes of the paper industry for structuring of the soils in the USSR. But so far, all this is done without a system, and only sporadically.

It has become inevitable at the present time to consciously control the processes of exchange between matter and nature. The urban economy — industry — farming — hydro economy form a complex system, which so far functions only in an elementary way. We have already determined the necessity of utilizing the soil cover as the most important link in this system.

National Land Registers

Among many problems which have to be considered and solved in the plan of action to preserve and utilize land resources, each

*N. Dhar. World Food Crisis and Land Fertility Improvement. Calcutta, 1972.

country should solve a more general problem — compilation of a national land register (census) based on detailed soil maps, on the data from a complex evaluation of biological productivity, and on the analysis of economic and biological values of the lands in perspective. For this purpose, it is necessary to do intensive work for several years, and to create special organs of the soil service. Without this, there will be no scientific-technical basis for designing and executing a long-term planned program on the optimal selection of the forms of economic utilization of the land and water resources, on the allotment of lands for improvement, and on the rational utilization of wastes and fertilizers.

This work will solve a number of questions from the viewpoint of governmental interests. In which way can one succeed in doubling or trebling the valuable biological production on farming lands of the given country, area, region, or farm? Which forms of melioration (simple, combined, complex), on which land parcels, and in which sequence should they be performed in order to reach the goals facing the agricultural and forest economy of the country?

When considering prospects for the development of the country, governmental planning organs should estimate possible exemptions and losses of fertile lands for various reasons (inundation, roads, inhabited points, new plants, etc.), and develop initial plans regarding the resources of the new lands in agriculture and forestry, etc.

It is necessary also to divide the country into regions on the basis of landscape-geochemical approaches to the territory, considering the neotectonics, geomorphology, and geochemistry of the locality.

The ways to most rationally utilize the landscape in the economy should be formulated approximately for the selected units of territory. They should include: optimal ratio of various lands, ratio of the areas of multi-year and one-year (particularly plowed) cultivation parcels, the proper network of roads, location of the future settlements, recreation and rest zones and sanatoriums, national parks, wildlife reservations, melioration for recultivation, utilization of disrupted lands and facilities, desirable and necessary meliorations on acquired and on still-nonarable lands (hydrotechnical, mechanical, chemical, agrobiological, phytomelioration, etc.). In the final analysis, these indicators will make is possible to group uniform subgroups of land similar in nature into categories.

In Holland, Canada, USSR, U.S.A., France, and other countries, there is already rich experience in the evaluation and similar grouping of soils.

* * *

The problem of the new understanding of the role of the soil cover in the ecological and biological balance of man and his material security worries the world. We are passing the time of excessive noise, agitation, sensational press — and dangerous passivity. We need action. A considerable part of the actions required is obvious, and requires implementation within the framework of each farm, region, area, and country.

The dialectic principle of unity of the world, the wholeness of nature and of universal relations can assist the scientists to find a place constructively for organisms and soil cover in the biosphere. At the contemporary level of knowledge and technology, the soil represents the most controllable component (by means of treatments, fertilizers, protection, melioration) among the main components of the biosphere. Water is controllable to a small degree (by means of irrigation, drainage — performed also through the soil). Organisms can be controlled to a relatively small extent (by the methods of genetics, selection, handling). Such components as atmosphere and climate are so far uncontrollable at present and in the foreseeable future. Therefore, we have to increase considerably the action of man, his technology and science, on the controllable components —

most of all on soils (melioration, chemization, recultivation), on water (distillation of salt waters, condensation of moisture, reduction of vaporization and transpiration), and on organisms (creation of the most productive forms on the basis of an accurate solution of the genetic code). It is just in these areas of science and technology that we should concentrate our efforts and apply scientific measures.

Translated for National Aeronautics and Space Administration under contract No. NASw 2483, by SCITRAN, P. O. Box 5456, Santa Barbara, California, 93108